

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

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To cite this article: R A Hammood and S M S Mohsin 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **365** 012061

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Steel fiber effect on mechanical properties of concrete mixture

R A Hammood *, S M S Mohsin

Faculty of Civil & Earth Resources, University Malaysia Pahang, Pahang, Malaysia

*E-mail: rasheed_eng2000@yahoo.com

Abstract. In this paper the influence of commercialize steel fiber with properties of hooked end with 60 mm length and 0.75 mm diameter on the mechanical properties of concrete with three varied volumes of steel fiber 0%, 1% and 2% by volume were added to concrete mixes have been investigated. The design compressive strength considered was 25 MPa. Cubes specimens of size 100 mm x 100 mm x 100 mm to test the compressive strength were prepared for the time of 7th and 28th day, and flexural specimens with 100 mm x 100 mm x 500 mm were prepared. In this study, after 28 days of curing, compressive and flexural strength were determined. The use of steel fiber has shown a significant change on the mechanical properties of the concrete, in particular the compressive and flexural strength with the increase of the volume fraction of steel fibers. The test results show that the use of steel fiber improves the compressive strength, moreover change the failure type to ductile failures.

1. Introduction

Concrete is a major construction material that has been widely used and growing in various application fields. Generally, concrete is a material that is strong in compression and weak in tension. Concrete is characterized by brittle failure, the loss of loading capacity, once failure is initiated. Fiber reinforced concrete (FRC) is commonly used and growing in civil engineering applications with new types of concrete [1-3]. In recent years, steel fiber reinforced concrete SFRC has gained increased popularity in construction industries [5, 6]. Steel fiber reinforced concrete members exhibit enhanced more ductile behavior and reduced crack and improving the structural behavior of reinforced concrete beams as mentioned by most researchers [2-4, 7-9]. The use of fibers for enhancing the mechanical properties of concrete increased significantly [8]. Traditional fiber reinforced concrete use various types of fibers. Steel fiber reinforced concrete has the ability of excellent flexural strength, ductility and prevent the propagation of a crack. The purpose of this experimental study was to study the behavior of single fiber and its ratio in the mechanical properties of concrete mixes with different dosages of commercialize steel fibers that has the properties of hooked end with 60 mm length and 0.75 mm diameter in normal strength concrete.

2. Experimental program

2.1. Materials Characteristics

The materials used in the preparation of tested specimens were obtained from local sources. Materials include ordinary Portland cement, crushed coarse aggregate, sand as fine aggregate, tap water, volume fraction of fibers. The concrete mix proportion was 1: 2.89: 2.57 (cement: fine aggregate: coarse aggregate) by weight. Properties of the steel fibers shown in Table 1. The steel fiber used is a commercialize fiber was hooked end with 60 mm length and 0.75 mm diameter by STAHLCON, see Figure 1. In present work, three



fiber volume fractions 0 %, 1 %, and 2% for steel fiber was considered. For the concretes containing fibers, the dosage of super-plasticizer was increased properly to maintain the slump around (10-30) mm. For admixture, super-plasticizer is added into the mixtures to improve workability and achieve the required slump.

2.2. Preparation of the specimens

In this study, experimental research was consisted of constructing and testing cubes at 7, 28 and prisms at 28 day for each concrete mixture. The control concrete mixture is designed in accordance to British Standards BS EN 206-1, 2000 for 25 MPa of concrete compressive strength used to construct the specimens. Three concrete mixtures were considered in this study including a reference mixture without fiber 0% volume of steel fiber and the remaining mixtures with single and fiber using different volume fraction of steel fiber 1% and 2%. The specimens demolded after 24 hours and then placed in water tank for 28 days, see Figure 4.

Table 1. Properties of steel fiber used.

Properties	Steel Fiber
Length, L (mm)	60
Diameter, D (mm)	0.75
Aspect Ratio, L/D	80
Tensile Strength (MPa)	1100
Density (kg/m ³)	7500



Figure 1. Steel fiber.

2.3. Testing procedures

For each mixture, the compressive tests were carried out on the six specimens of cubes with a standard size of 150 x 150 x 150 mm at 7th, 28th day to determine the concrete compressive strength. The flexural tests were carried out on the three specimens of prisms with a standard size of 100 x 100 x 500 mm at 28th day to determine the concrete flexural strength, as recommended in British Standards BS EN 12390-3, 2009 and BS EN 12390-5, 2009, respectively. During the compressive and flexural tests, the load was recorded. All the specimens were tested to failure under loading system. The universal testing machine was used for testing the compressive and flexural strength of concrete were illustrated in figure 2, 3, respectively.



Figure 2. Compression test Machine.



Figure 3. Flexural test Machine.



Figure 4. Specimens curing.

3. Results and Discussion

This section was presented the various tests results that were conducted in the concrete laboratory. The specimens were cured and tested at the specified days. However, a total number of 18 cubes and 9 prisms were tested of concrete mixes.

3.1. Slump Test

Slump test were performed on fresh concrete. In this study, Slump class had been designed to be between 10 and 30 mm. when the percentage of fiber increases from 1% and 2%, the mixes becomes stiffer in workability results and shown low slump value compared to the slump of plain concrete with 0% of steel fiber. The slump of the concrete was measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone, see Figure 5. Slump test results of all concrete mixes were tabled in Table 2. Test results showed that slump of concrete decreased as the volume of steel fibers increased. In general, the addition of fibers in concrete caused significant effect in the concrete workability.

However, the overcoming of this problem could be through the use of the admixture. In order to achieve a slump value, super-plasticizer is being used to improve workability and achieve the required slump. However, slump values represents the designed range of the slump test after added super-plasticizer was achieve the required slump. As shown in Figure 6, the addition of fibers to concrete mixture reduced the workability of concrete and the dosages of super-plasticizer were adjusted to maintain the workability.



Figure 5. Concrete Slump Test

Table 2. Slump Testing Results of mixtures.

No.	Volume fraction $V_f\%$	Slump mm
1	0%	20
2	1%	22
3	2%	17

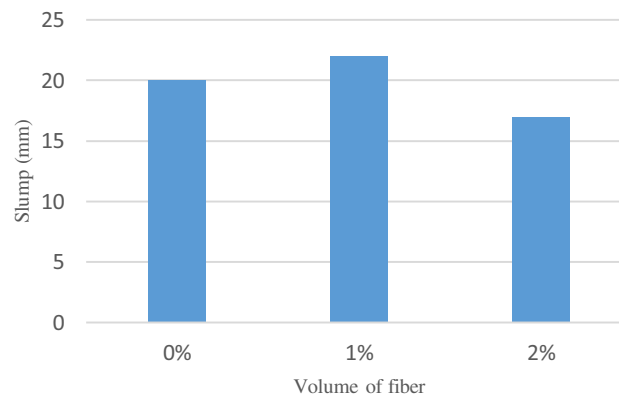


Figure 6. Slump testing results concrete mixtures.

3.2. Compressive Strength Test

In this section the compressive strength values obtained from an average of three specimens. Table 3 shows the experimental results of average compressive strength of all the concrete mixes at 7th and 28th day. It is noteworthy that all concrete mixtures has reached more than its target compressive strength 25 MPa. It can be seen from the results that, initially on the 7th day of the testing, compressive strength of the all concrete mixtures with fibers are higher than the control mixture. From the results were listed, it clearly demonstrates that the compressive strength increases with increasing fiber volume fraction. Compressive strength of control concrete mixtures was 32.12 MPa at 28th day, whilst compressive strength with volume fractions 1% and 2% of steel fiber increasing when were compared with control mixture up to 6.88% and 36.42%,

respectively. This result demonstrate that the additional of steel fibers increase the compressive strength of concrete matrix. See Figure 7.

Table 3. Compressive strength of concrete mixtures.

Batch No.	V_f %	Compressive Strength (MPa)	
		7 Day	28 Day
1	0%	30.29	32.12
2	1%	30.43	34.33
3	2%	38.13	43.82

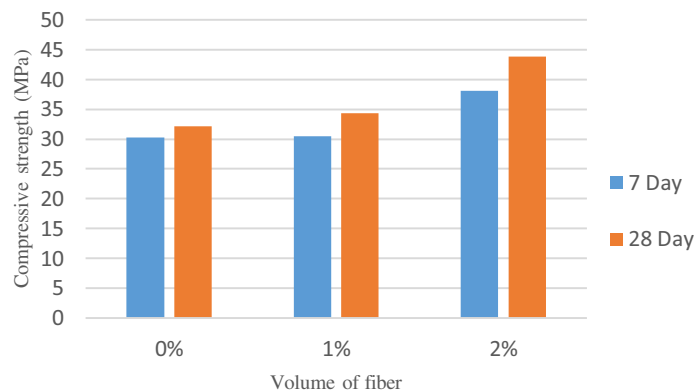


Figure 7 Compressive strength of concrete mixtures.

3.3. Flexural Strength Test

Flexural strength test results of the concrete mixtures are presented in Table 4. When the fiber volume fraction increased from 0%, 1% and 2% flexural strength increased from 5.35 to 10.59 MPa. The test is done by testing on prisms with size of 100 x 100 x 500 mm. Upon observation of the results, it can be noted that the inclusion of steel and hybrid fiber into concrete mixture has an excellent influence on the flexural strength of the concrete mixtures compare to of conventional concrete with 0% of steel fibers. After analysis of all the results of concrete mixture specimens, it can be observed from the findings that there is an enhancement in the behavior of concrete specimens with 1% of steel fiber by 137.19%, while enhancement by 97.94% with 2% of steel fiber when compared to conventional concrete specimens, see Figure 8. Moreover, the test results indicated that the ability of the fibers in controlling the crack propagation of the specimens was demonstrated by the change of the failure mode from brittle to a ductile manner. According to these test results, it seems that the steel fibers have excellent effect on the flexural strength of concrete.

Table 4. Flexural strength of concrete mixtures.

Batch No.	V_f %	Flexural Strength (MPa)
1	0%	5.35
2	1%	12.69
3	2%	10.59

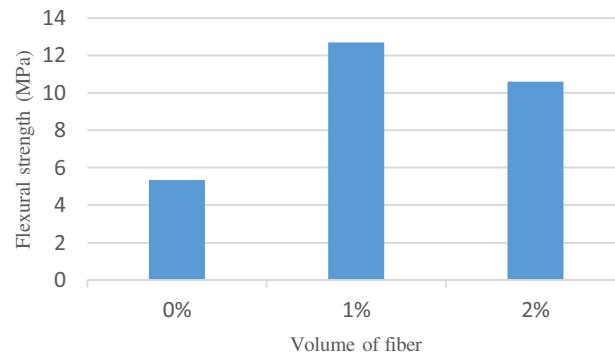


Figure 8. Flexural strength of concrete mixtures.

3.4. Cracking pattern and mode of failure

Cracking pattern and Failure mode of concrete mixtures are presented in Figure 16. In general the crack start at mid span at bottom and extended toward up between the two points of loading. Fiber reinforced concrete has been found to increase the tensile strength of concrete and has potential to delay the cracking propagation and change the mode of failure from brittle to ductile manner when compared to conventional reinforced concrete. The reason behind these higher strengths may be the higher amounts of fibers that limit the propagation of the cracks. For plain concrete, a sudden reduction in load was recorded and breaking as seen in Figure 9. As seen from these results, substantial increases were obtained by the use of steel fiber and these increases in the fracture energy depend on the fiber content as seen in Figure 10 and Figure 11. These increases may be accepted as the indication of changes in the ductility of concretes compared to plain concrete.



Figure 9. Cracking pattern at the failure of concrete with 0% of steel fiber.



Figure 10. Cracking pattern at the failure of concrete with 1% of steel fiber.



Figure 11. Cracking pattern at the failure of concrete with 2% of steel fiber.

4. Conclusion

Based on the test results obtained, it may be concluded that the compressive strength and flexural strength of the concretes were affected significantly with the use of steel fibers.

Compressive strength value obtained increased as the fiber volume fraction increased compared to the conventional concrete mixture. It can be clearly seen that the compressive strength was improved by the addition of steel fiber about 6.88% and 36.42% with volume fractions 1% and 2% of steel fibers, respectively.

The results show that the flexural strength has significant increased with the increase of volume of the steel fibers. In other words, the presence of the steel fibers had increased the flexural strength about 137.19% and 97.94% with 1% and 2%, respectively.

Moreover, the test results indicated that the ability of the steel fibers in controlling the crack propagation of the specimens was demonstrated by the change of the failure mode from brittle to a ductile manner. On the other hand, indicated that the use of fibers may become a more desirable solution for steel fiber reinforced mixtures and environmental needs.

Acknowledgments

The authors would like to acknowledge the support and kind assistance received from the technicians in the Concrete Structural Laboratory of Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang (UMP) in conducting the experimental work. This work was financially supported by UMP through Research Grant Scheme (RDU1803168).

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